INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 17, Issue 2, 2026: 679-690 www.ijcs.ro
DOI: 10.36868/IJCS.2026.02.17

IN FIELD PROTECTION OF THE POTTERY USHABTI FROM THE TOMB OF IUROKHY AT SAQQARA USING EFFICIENT CONSOLIDATION FORMULATION

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Abstract
Saqqara, the significant cemetery of Memphis, has served as a funerary site for approximately 3,500 years, yielding a wealth of archaeological treasures, including Ushabti statues from the tomb of Iurokhy, the chief army commander during the reign of King Ramesses II. This study focuses on the analysis and consolidation of these Ushabti statues, which are believed to represent different ages of a woman and bear hieratic inscriptions potentially linked to her name. These statues are mainly made of pottery; therefore, considerable damage, including dirt accumulation and fragility of the pottery body, has occurred to their features. The Ushabti statues, which appeared in the tombs since the Middle Kingdom onward, served as funerary figures representing the deceased in the afterlife. These statues are crafted from faience, stone, and burnt clay; their production was peaked during the New Kingdom and became increasingly common by the 21st Dynasty. To ensure the preservation of these antiquities, this research focuses on the consolidation of these found antiquities using a formulation that was tested and had effective results in a previous work to reveal its efficiency in their protection. Many challenges were facing this consolidation process, with the main one being the effective cleaning of the statues, which requires understanding the types of dirt and the changes that ensued in the materials over time. Subsequently, consolidation techniques utilizing both inorganic and organic materials were applied to enhance the durability and waterproofing of the pottery to protect it from any environmental damage. The study mainly aimed to investigate the chemical and mineral composition of the Ushabti statues, then analyze the deterioration characteristics that arose on the statues from the various environmental factors, and finally use the consolidation formulation to ensure the full protection against deterioration factors.

Keywords*: Ushabti statues; Egyptian Ushabti; Deterioration; Consolidation*

Introduction

Saqqara is one of the most important cemeteries of Memphis; it occupies the central part of the larger Memphite necropolis. Its geographic coordinates are 29° north and 31° east, only 30 kilometers south of Cairo [1]. Moreover, the North Saqqara Plateau, situated south of the King Unas walkway (path), emerged as a significant location within the Memphis cemeteries during the New Kingdom. This area is where the archaeological team from the Faculty of Archaeology at Cairo University discovered numerous tombs resembling temples dating back to the Ramesside era [2]. Saqqara was a funerary site for approximately three and a half thousand years until the Late Period/early Ptolemaic era. The archaeological mission of the Faculty of Archaeology, Cairo

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University, operating in Saqqara in the 2022 season, succeeded in uncovering the tomb of the chief army commander during the reign of King Ramesses II (the Nineteenth Dynasty—the New Kingdom), who was called "Iurokhy." The mission found many small statues known as Ushabtis in the tomb that may belong to one of his grandsons [3]. Iurokhy's titles reflect the significant positions he detained in the military and royal court. These positions, including Royal Scribe, High Steward, and General of the Army, underscore his importance and influence in those areas [4].

Iurokhy built his tomb about 50 m north of Maya's tomb, on a slight rise from the plateau, and had close ties to the king. Iurokhy, who served as the first attendant at the Theban temple of Ramesses II. The tomb, which is constructed from mudbrick, measures approximately 40 meters in length. It features three chapels on the west side (with the central chapel topped by a pyramid), an inner courtyard with columns, a "statue room" that includes four side chapels, and a forecourt that is broader than the eastern section of the tomb. Two of the side chapels can be entered from the forecourt, while the other two are accessible from the inner courtyard. The tomb well can be reached from the final area of the tomb, as shown in Fig. 1 [1].

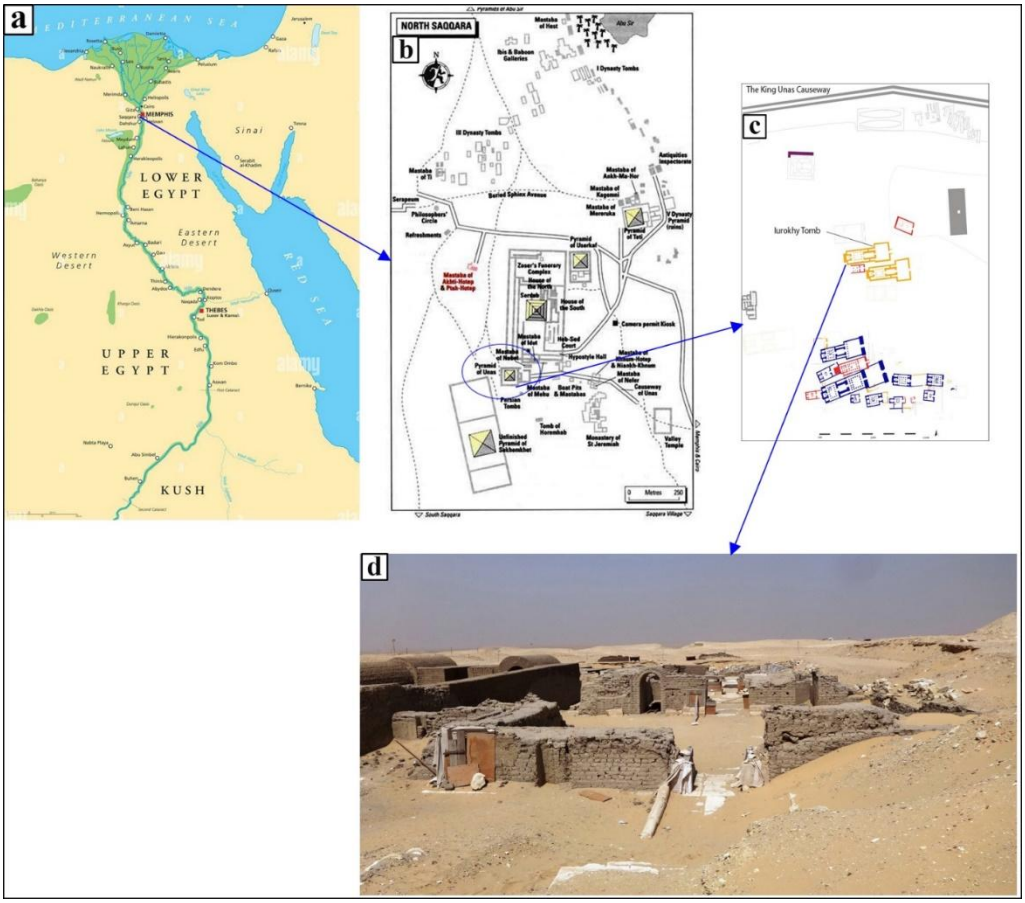

Fig. 1. (a) Egypt map, (b) Saqqara archaeological site, (c) the layout of the New Kingdom burial site located south of Unas's causeway, and (d) the location of Iurokhy's tomb containing the ushabti statues

The Ushabti statues appeared in the tombs of kings and individuals since the beginning of the Middle Kingdom era and continued until the Ptolemaic era, i.e., their presence was mainly limited to the tombs of kings, the upper class, and wealthy people because the artist of the royal palace was the one who was in charge of forming these statues and then placing them inside the cemetery. Besides, the Ushabti not only assumed human shapes, but they also presumed sacred animal forms [5] as well. It is noted that the ushabti statues of a funerary nature were placed next to the deceased as an alternative to represent him in the resurrection in the other world [6]. Ushabti statues are mostly made of faience, stone, burnt clay, and chrome since the era of the New Kingdom, and since then their production has increased [7]. From the 21 dynasties, the Ushabtis statues became common and numerous in graves. In some tombs, the floor was covered with many Ushabti figurines, while in others the Ushabtis were neatly packed into boxes [8].

The statues were found in the Iurokhy tomb in Saqqara, under one of the domes, which required deep analysis before the conservation process. These statues represent the different ages of a buried lady and bear hieratic inscriptions written in an abbreviated manner that may refer to her name [9]. Although these statues were found in the tomb of Iurokhy, the army commander chief in the era of King Ramesses II, they and their artistic features were dated to the late era [10]. Pottery, which is the main material in the composition of the Ushabti statues, suffered from many manifestations of damage represented by the heavy accumulation of dirt and salts, in addition to the fragility of the pottery body as well.

The mummy-form Ushabti was wearing a tripartite wig with black striations and was crudely modeled in low relief on the face. The arms were crossed right over left on the chest, while the face of the Ushabti indicated bad details; furthermore, the eyes and brows were added roughly. The purpose of the statue may be the representation of a mother goddess or other different purposes. Several statues seemed to have been votive donations to Hathor associated with fertility, and the heavy wigs that were depicted on several of these statues may also suggest fertility [11]. Consequently, it can be speculated that the figures were made to ensure the fertility of women. Fertility may also relate to rebirth in the afterlife, especially with the diversity of representation of life stages through these statues.

Restoration and conservation of antiquities are essential processes that must be done to preserve antiquities from deterioration [12]. In addition, archaeological and historical object restoration is always a valuable source of information about human behavior and cultural values [13]. Often, the first and most difficult task is the cleaning step, which involves getting rid of dirt, which is defined as any foreign substance that is located on the outer surface. Understanding the type of dirt and the changes that happened to the exterior and interior of the object over time is essential during this process [14].

The consolidation technique uses inorganic or organic materials for conservation and restoration. Furthermore, the consolidation process usually increases the durability of the materials by providing waterproofing. Moreover, pottery should be treated with a substance that can strengthen its inner structures and protect it from water by using a water-repellent material to prevent deterioration. Polymeric materials reduce pottery degradation, which is caused by weathering processes or air pollution [15]. Additionally, the effectiveness of consolidation and the treated object surface can affect the mechanism and the competence of the consolidant [16]. Besides, consolidants are most effective when they achieve good penetration into the pores of the objects [17]. This study emphasizes the crucial significance of the examination and analysis in offering scientific data as a foundation for any proposed intervention and restoration efforts. The various investigation methods can deliver insights into the structure and composition of heritage

materials, which are essential for developing appropriate conservation strategies that were tailored to be proper to these materials.

Consequently, this research aims to investigate the chemical and mineral composition of the pottery statues. In addition to the deterioration, characteristics resulted from the different environmental factors that have affected the pottery statues physically or chemically. Also, some restoration methods will be applied to show the aesthetics of the vessels and prepare them for museum display.

Experimental part

Archaeological and artistic description

Ushabti statues first appeared in the tombs of kings and notable individuals at the beginning of the Middle Kingdom and continued to be used until the Ptolemaic era. Their presence was primarily restricted to the tombs of royalty, the upper class, and wealthy people because they were crafted by artists from the royal palace and placed in the cemeteries.

Additionally, ushabtis were not limited to human forms; they also were embodied as sacred animal shapes, such as that of the Apis bull, which depicted a mummy-like figure with a human body and a bull's head [8]. Six pottery shabtis in the shape of mummies, with varying sizes, were discovered in the Iurokhy tomb at Saqqara and placed together along the east wall of the tomb. These pottery figures showed remnants of whitewash, which were applied to their bodies, leaving the areas not covered by unpainted linen. Each shabti features a simple tripartite wig with arms crossed over the chest, and their feet are designed to curve forward. On the front of the statues, there is a line of hieratic text in various sizes and orientations, mentioning the feminine name *hnwt-Mwt*, which aligns with the shabtis' feminine characteristics. The texts on the shabtis are all the same and written in black ink. Typically, shabti inscriptions were done in hieroglyphs or cursive hieroglyphs. At the same time, those written in hieratic are usually found on stick-type specimens from the Second Intermediate Period and the early New Kingdom. The hieratic inscriptions on these shabtis consist of a title followed by a name, and the paleography of some of the hieratic characters provided clues for dating. These features indicated that these shabtis can likely be dated to the end of the New Kingdom, as shown in Fig. 2 [2].

Fig. 2. The Ushabti statues extracted from the Iurokhy tomb in Saqqara

Materials

The study was conducted on six Ushabti statues that were extracted from the tomb of Iurokhy in the Saqqara region of the excavation mission of the Faculty of Archeology, Cairo University, in the season 2022. These statues manifested various damages that required intervention to perform different treatment operations. These altered methods of inspection and investigation were used to identify the aspects of damage that were incurred by these statues.

Preparation of the Ushabti statues for analysis and their consolidation process

Cleaning

Cleaning is considered the most important and the first step in the conservation of artifacts and artwork. In terms of treatment and maintenance, it is always recommended to begin with the mechanical cleaning to the greatest possible extent before starting the chemical cleaning in its various forms using simple and small tools [18]. Though the pottery surface is damaged by the aggressive mechanical cleaning, which also encourages deposits to penetrate deeper into the pores. Therefore, the mechanical cleaning must be done very carefully. At this first stage, brushes of different sizes can be used to clean the accumulated dirt on the surface [14]. Distilled water also shows good results in cleaning and dirt removal. Additionally, a 1:1 purified mixture of water and ethyl alcohol can be employed, as shown in Figure 3 [19].

Fig. 3. The Ushabti statues during the cleaning and consolidation process: (a) mechanical cleaning with a brush, (b) chemical cleaning of the body with ethyl alcohol, (c) application of the consolidation materials, (d) after treatment of the Ushabti statues

Consolidation

It is common for pottery to require a consolidation procedure, which joins granules and enhances the physical and mechanical qualities of the items by consolidating their interior structure [17]. Therefore, one of the most direct and efficient ways to reduce the rate of deterioration of ancient pottery artifacts is to use appropriate consolidating materials [15]. Based

on previous work, a composite containing a cerium-strontium aluminate pigment (SrAlCe) was integrated into a styrene acrylic polymer, which formed a composite that was prepared, characterized, and applied. Styrene acrylic (St-Ac) polymer was used with low solid content (3%) to yield a formulation with low viscosity to facilitate their penetration through the pottery samples. The prepared pigment was included with percentages of 7% of the total solid content of the formulation [20]. The prepared formulations were applied to pottery samples using a fine brush to cover all the sides of the cubic samples, and then the samples were left to cure for about one hour. After that, the process was repeated till the demanded film thickness was obtained, as shown in Fig. 3.

Characterization methods

X-ray diffraction (XRD)

The X-ray diffraction (XRD) was used to identify the chemical structure of the Ushabti statues, and it was obtained at room temperature using a Philips diffractometer (Model PW 1390) in Japan, employing Ni-filtered Cu Kα radiation (λ = 1.5404 Å), with a diffraction angle (2θ) that was scanned at a rate of 2°/min.

Morphology of the Ushabti surface before and after consolidation

Digital Microscope

An HD color CMOS sensor, model (USB) ×4; magnification from 200 to 1600×; resolution up to 640×480; focus range from 15 to 40 mm; frame rate up to 30 PPS; and image format BMP/JPG were used to estimate the surface morphology of the samples.

Scanning electron microscopy with energy dispersive X-ray (SEM-EDX)

The morphology and the surface of the Ushabti were determined using scanning electron microscopy (SEM) (JEOL JX 2840) and a micro-analyzer electron probe (Japan).

Results and discussion

X-ray diffraction (XRD)

The XRD analysis of the samples is presented in Fig. 4. The sample consists of several components, including quartz, illite, diopside, hematite, calcite, and halite.

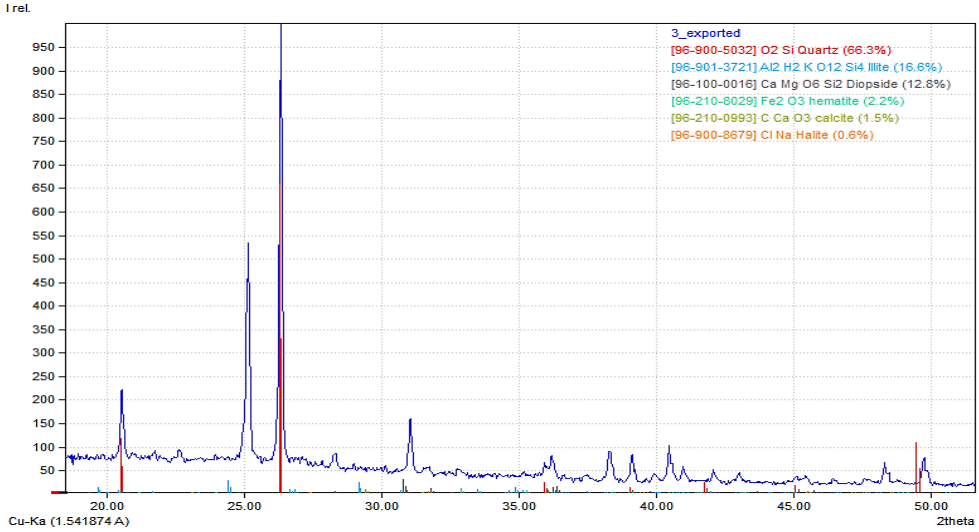

Fig. 4. The X-ray diffraction pattern of the sample of pottery Ushabti

Quartz is the predominant component, while the incorporation of silicon dioxide into the clay was crucial during the manufacturing of these statues, because it helps to minimize the shrinkage during drying and firing. Traditional methods for estimating firing temperatures involve analyzing either the minerals or the newly created mineral phases that emerged from the firing process. Although the composition of the raw materials is the primary factor influencing the properties of the finished pottery, the firing temperature is crucial as well. If the correct firing temperature is not achieved, the transformations that turn a malleable piece of clay into durable pottery may not come about. As the firing process progresses, the crystal structures begin to break down once their stability parameters are surpassed, leading to the formation of new mineral phases [21].

The mineral composition of the sherds helps in estimating the accurate firing temperatures, with the presence of illite suggesting that they were subjected to temperatures around 900°C. Illite disappeared at 950°C, which is considered effective evidence that the firing temperature of the ushabti statues was around 900°C [22]. Diopside can be identified starting from 850ºC, and this suggests that the statues were fired at temperatures between 800 and 900ºC [23]. Diopside is mostly formed at high temperatures and results from a reaction that involves three oxides: CaO from calcite, MgO from montmorillonite, and SiO_2 from kaolinite, which is the main constituent of clay. Natural diopside typically possesses higher concentrations of SiO_2 and lower amounts of CaO and MgO [24]. By examining the changes that occur in the raw clay minerals after firing, it can be inferred that the potential technological approaches used by artisans and the temperature ranges their kilns were achieved. Additionally, the firing temperature is a critical factor in the pottery-making process because it affects the overall microstructure of the pottery, and in the long run it influences its long-term durability and resistance to degradation [25].

Halite is a soluble salt that is formed through the interaction of burial soil with pottery. Sources of these salts may include groundwater or rainwater that seeps through the soil surrounding the artifacts. These salts can cause significant damage by penetrating the pores and crystallizing on the surface, leading to fragility [26]. Calcite serves as the slip layers that are applied to the outer surface. Calcite decomposes into CaO and CO_2 starting roughly at 650°C and is fully completed at 950°C, which means that it vanishes at this temperature. This suggests that the firing temperatures were below 950°C, likely around 900°C [27]. The findings that hematite suggests that these statues were in an oxidizing environment (a process that reflects a clean-burning atmosphere with plenty of oxygen with a clear flame and relatively little smoke) during their production; this accounts for the reddish-brown color that was commonly noticed on their surfaces [28]. Hematite is also one of the primary colors used in painted pottery [29].

The surfaces of New Kingdom ushabti statues were finished in different ways. They could be smoothed while the clay was still damp or add a slip layer before burnishing [30]. The New Kingdom was a time of prosperity, and this was evident in pottery production. During this period, pottery was crafted with great skill, especially the items created on the potter's wheel. A potter's wheel is a commonly used tool by potters to mold clay. It features a rotating platform, typically powered by foot, enabling the potter to produce accurate symmetrical shapes. Ancient Egyptians used it considerably to make pottery vessels of various sizes, and the mold was also employed to shape the Ushabti statues [31].

Morphology of the Ushabti surface

Digital Microscope

The results of the digital microscope displayed in Fig. 5 revealed that the Ushabti statues suffered from many phases of damage; among these damages was the dense dirt that accumulated

on the pottery body. In addition, the white slip layer peeled off and disappeared from several areas of the pottery body surface. In addition, the examination reveals the fragility of the pottery body and the weakness and disintegration of the black ink used to write on the surface of the statues. The visual and physical characteristics of ink are influenced by its composition, type and quantity of binder, particle size, archaeological context, and preservation history. For example, black ink on statues showed varying color tones and physical consistency due to different environmental conditions in the burial environment, including factors like salt crystallization and soil pressure. Additionally, the exposure to bright light after extraction from the burial soil can further affect these properties [32]. Carbon inks are highly vulnerable to environmental damage because of the weak bond between the ink and the pottery surface, leading to the loss of some ink areas. In contrast to pure carbon inks, which can stay on the surface of writing support. Inks containing tannins and metallic ions can penetrate the substrate, making them harder to remove [33].

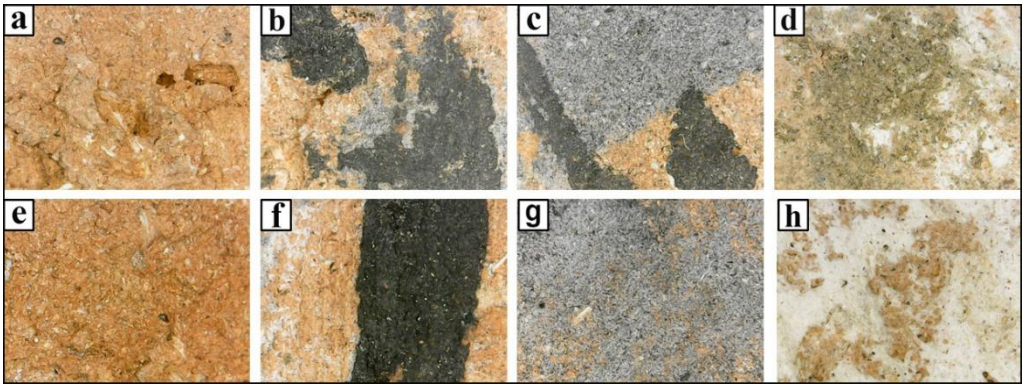

Fig. 5. The Ushabti statues before and after consolidation. (a, b, c and d) Before consolidation, which shows fragility of the pottery body's cracks, separations, weaknesses in the black ink, and accumulation of dirt and sand. (e, f, g and h) After consolidation which show good coating for surface and fixing the black ink and the color

The figure also illustrates that the outer surface of the Ushabti statues appeared red due to the application of an outer slip layer that enhanced the smoothness of the surface and sealed the larger pores. This coloration was commonly seen during the late Eighteenth Dynasty. Examinations also indicated that the body of the Ushabti statues includes fine grains of white limestone powder. Additionally, this fabric features small sand grains and voids created by incorporating straw into the clay during manufacturing. These features are indicative of pottery produced in the New Kingdom period. The color of the pottery varies from dark red to reddish brown [34].

Figure 5, which showed the photos of both untreated and treated pottery samples, made it clear that the untreated sample exhibited numerous disintegrated patterns and visible cracks. In the case of the sample treated with St-Ac-P7%, a homogenous and smooth surface was detected. Furthermore, this sample offered a good dispersion of the consolidated material without showing any brightness on the surface. Additionally, the sample covered with 7% St-Ac-P created an unnoticeable coating that provided little contrast with the backdrop.

Scanning electron microscopy with energy dispersive X-ray (SEM-EDX)

The SEM photographs of one statue's broken part indicated a considerable accumulation of dust on the surface of the pottery statues, along with the presence of salt crystals, which necessitates intervention during the cleaning process. Additionally, the statues exhibited varying

sizes of gaps within their bodies, resulting in increased fragility and weakness and highlighting the need for a strengthening procedure to prevent further damage (Fig. 6). The EDX analysis revealed that the clay, which is the primary component of these statues, contains 4.16% aluminum oxide and 12.05% silica. Moreover, the high percentage of calcite, which is about 14.82%, suggested the usage of calcium carbonate in the slip layer. The entire surface of the pottery may have been painted for decorative purposes or to reduce permeability. There are two main types of pottery slips: clay-rich slips and glazes. The slip used on these statues is identified as a clay-rich slip, which can be categorized into permeable and impermeable types. Permeable slips are generally opaque, porous, and exhibit minimal changes during firing, typically appearing in red or white. White slips are usually made from kaolinite-rich clays or clays with very low iron content [35].

Furthermore, the sample showed a high concentration of carbon dioxide approximately 16.13%, indicating that the inscriptions on the pottery statues were created using carbon ink. Historically, carbon ink was widely used in ancient writing, including all Demotic texts. This ink is a mixture of a binding agent, such as Arabic gum or animal glue with a pigment or dye [36]**.** Prior studies on inks used in Egyptian writing have shown that black pigments were primarily derived from amorphous carbon, including soot ("lamp black"), charcoal, or bone black. The production of carbon ink involved incorporating the water more than once: initially to create dry ink by mixing soot with a binder dissolved in a small amount of water, which was then dried and formed into granules for storage. When ready to write, the scribe would mix these granules with a second amount of water to create liquid ink. The used binder was typically Arabic gum from the Acacia nilotica (L) tree [32].

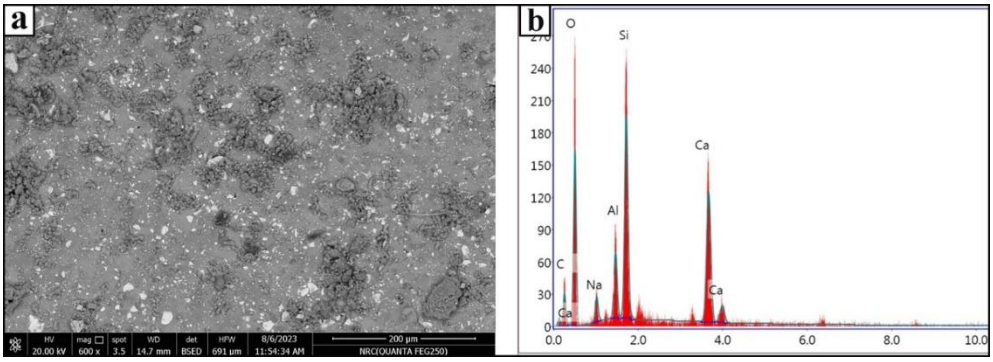

Fig. 6. SEM pictures and EDX spectrum of pottery statues

Conclusions

The analysis and consolidation of Ushabti statues from the tomb of Iurokhy at Saqqara underscore the importance of preserving Egypt's rich archaeological heritage. These funerary figures, crafted primarily from pottery, have endured significant deterioration due to environmental factors and the passage of time. This study employed a systematic approach that included the evaluation of their chemical and mineral composition besides the identification of deterioration patterns, providing insights into the preservation challenges faced by these artifacts. Additionally, the consolidation techniques developed and tested in this research verified promising results in enhancing the durability and waterproofing of the pottery, offering a viable solution to mitigate further damage. Effective cleaning methods tailored to the specific types of

dirt and degradation observed are crucial for successful consolidation. Through the application of both inorganic and organic materials, the consolidation process not only aimed to protect these statues from environmental harm but also ensured their longevity for future generations to study.

Acknowledgments

The authors would also like to express their deep gratitude and appreciation to Prof. Dr. Ola El-Agizy, Head of the Cairo University Archaeological Mission at Saqqara; Dr. Tarek Tawfik; and Dr. Nader El-Husseiny for their assistance and encouragement during research at the Saqqara site and for providing historical information about the tomb of Iurokhy. We also extend our sincere thanks to Dr. Khaled Hassan for his assistance in interpreting the hieratic texts. We also extend our sincere thanks to Mr. Magdy El-Beheiry, Director of Excavations; Mrs. Weam Ashour; and Mr. Montaser Kamal for their dedicated efforts in restoring the ushabti statues.

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Received: October 13, 2025
Accepted: April 10, 2026